Biased feedback influences learning of Motor Imagery BCI

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Jelena Mladenovic[1,3], Jeremy Frey[2], Jeremie Mattout[3] & Fabien Lotte[1]

[1] Potioc, Inria / LaBRI (CNRS / Bordeaux INP / Univ Bordeaux),France; [2] Ullo Labs La Rochelle, France; [3] DyCog, CRNL Inserm U1028 Lyon, France

***Introduction**:* Various user trainings were proposed to assist the user in accomplishing Motor Imagery (MI) BCI task, e.g. the use of positive (biased) feedback which is an optimistic representation of one's labeled brain activity has shown to increase performance [1] or learning [2]. On the contrary, in [3] positive feedback decreased while negative increased user learning within one session. In order to better understand the benefits of biased feedback on performance and learning during the BCI training, we consider user states such as workload and the flow state, a state of optimal cognitive control, immersion, and pleasure, which has shown to correlate to performance [4].

***Material, Methods and Results**:* 30 participants (12 women, mean age: 28.56 years, SD: 6.96) were split between 3 groups: 1. no_bias, 2. positive bias and 3. negative bias, where the SVM classifier output was biased in real-time using a cumulative beta distribution function. Participants engaged in 2 sessions, each consisting of a calibration (2 runs) and testing (6 runs). A run contained 20 trials per class and lasted ~5 mins. Users played the Tux Racer game using left-right hand MI. After each run, workload and flow states were assessed with NASA-TLX [5] and EduFlow [6] questionnaires, respectively. Online performance was calculated as the peak performance of the classifier. Learning rate was the slope of the linear regression of online performance over runs within a session, e.g. above zero suggested positive learning, while below zero suggested a decrease in learning. We found a significant interaction: group×session in learning rate (2-way ANOVA, $p<0.01$), Fig 1.A; but there was no difference in performance between groups. We found correlations ($p<0.05$, corrected with FDR) between state of flow and both performance (Pearson's $r=0.30$) and learning rate ($r=-0.20$); no correlation between workload and performance but a correlation with learning rate ($r=0.13$). Finally, we found a significant difference between groups, $p<0.05$ for the cognitive control dimension of EduFlow score as in [4], Fig 1.B.

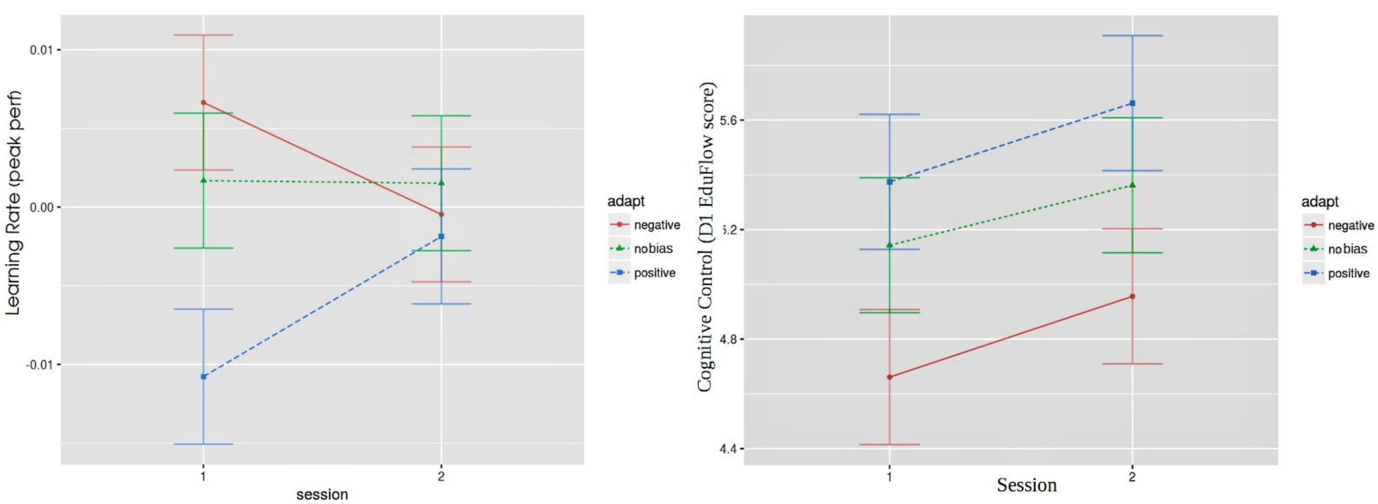

Fig 1.A. (left) ANOVA of learning rate. B. (right) ANOVA of EduFlow score (cognitive control), between sessions for each group.

Discussion: Negative feedback [3] as well as negatively biased feedback (shown here) can increase learning, however it applies only short term, as it can severely decrease learning from session 1 to session 2 (red line in fig 1.A. from above to below zero learning rate). On the other hand, positively biased feedback remained in the negative, decreasing learning.

Significance: Biased feedback influences directly user learning, and user sense of control, but not necessarily performance. Furthermore, flow state may be useful for performance as in [4] but it is suboptimal for learning (negative correlation). This study reveals the need to adapt biased feedback between sessions, e.g. starting with negative, through no bias, to positive.

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